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BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES

Application Number: 10/771,522
Filing Date: February 5, 2004
Appellant: Junpei OGAWA et al.

Martin J. Cosenza
For Appellant

EXAMINER'S ANSWER

This is in response to the revised appeal brief filed August 21, 2006 appealing from the final Office action mailed on September 22, 2005.

(1) Real Party in Interest

A statement identifying by name the real party in interest is contained in the brief.

(2) Related Appeals and Interferences

The examiner is not aware of any related appeals, interferences, or judicial proceedings, which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

(3) Status of claims

The statement of the status of the claims contained in the brief is correct.

(4) Status of Amendments after Final

The Appellant's statement of the status of amendments after final rejection contained in the brief is correct.

(5) Summary of claimed subject matter

The summary of claimed subject matter contained in the brief is correct.

(6) Grounds of rejection to be reviewed on appeal

The Appellant's statement of the grounds of rejection to be reviewed on appeal in the brief is correct.

(7) Claims Appendix

The copy of the appealed claims contained in the Appendix to the brief is correct.

(8) Evidence Relied Upon

The following is a listing of the evidence relied upon in the rejection of claims under appeal.

10-306317	Japanese Utility Model	November 17, 1998
5,048,368	Mrdjenovich et al.	September 17, 1991
5,737,976	Haman	April 14, 1998

The English translation of Japanese Utility Model No. 10-306317 (hereinafter JP'317) is attached as an Appendix to the Examiner's Answer.

(9) Grounds of rejection

The following grounds of rejection are applicable to the appealed claims:

I. Claims 19 and 21-25 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. This rejection is set forth on pages 4 and 5 of the final Office Action on September 22, 2005.

II. Claims 19 and 21-25 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Appellant regards as the invention. This rejection is set forth on page 5 of the final Office Action.

III. (1) Claims 1, 2, and 4 are rejected under 35 U.S.C. 102(b) as being anticipated by JP'317. This rejection is set forth on pages 6 and 7 of the final Office Action.

(2) Claim 1 is rejected under 35 U.S.C. 102(b) as being clearly anticipated by Mrdjenovich. This rejection is set forth on page 7 of the final Office Action.

(3) Claim 1 is rejected under 35 U.S.C. 102(b) as being clearly anticipated by Haman. This rejection is set forth on page 7 of the final Office Action.

(10) Response to argument

The Examiner's response in the final Office Action is incorporated herein by reference. In the following, the Examiner addresses the arguments that have not been treated in the final Office Action.

I. 35 USC 112, First Paragraph

A. Preliminary Matter

Appellant contended that the language of claim 19 is supported by the original application as filed because claim 19 is almost a *verbatim* copy of both claim 19 as filed and a paragraph in the specification.

The Examiner respectfully submits that the instant rejection under 35 USC 112, first paragraph, is based on a lack of an adequate written description, not new matter. The issue whether Appellant's claims were supported by the application as filed or not is not germane since the rejection is not based on new matter. The Examiner used Form Paragraph 7.31.01 in MPEP 706.03(c) that covers the inadequate description including new matter situations. In the instant case, the new matter situations are not applicable. Appellant's arguments on pages 10-14 of the brief regarding new matter issue are immaterial.

B-D. Written Description Issue

Appellant argued that the failure to show a claimed feature in the drawings of an application in view of an *adequate* originally filed claim and/or specification does not and cannot result in a written description deficiency. See page 15 of the brief.

The Examiner agrees that the failure to show a claimed feature in view of an adequate written disclosure may not result in an inadequate description. In fact, each case depends on its own fact. In the instant case, Appellant not only failed to show the claimed feature but also failed to provide an *adequate* originally filed claim and/or specification.

First, Appellant's specification describes the portion Q that has a cross sectional area 1.5 times larger than that of the portion P of the smallest cross sectional area. See Example 1 described in paragraphs [0141]-[0147] of the specification. Example 1 is illustrated by Fig. 1 as seen in paragraph [0142]. 37 CFR 1.83(a) requires that the drawings must show every feature of the invention specified in the claims. 37 CFR 1.84(p)(5) further requires that the reference characters mentioned in the description must appear in the drawings. Appellant failed to explain

as to why Appellant could show schematically the portions P in Fig. 1, but not the portions Q that is likewise mentioned in the specification.

Second, Appellant admitted that the lowest fatigue strength portion is *at least in part* governed by material property. However, Appellant asserted that there is no way to schematically show this feature. This contention is in direct conflict with Appellant's own drawings. In fact, Appellant's Figs. 1, 7 and 13 show the relationship among the cross sections P and the corresponding strengths/strains of these sections P. Thus, it is reasonable to infer that Appellant could similarly show the relationship among the cross sections Q and the corresponding strengths/strains of these sections Q. Appellant failed to explain as to why Appellant could show the charts of the relationships among the cross sections of portions P versus the strengths but Appellant could not provide any similar charts related to the cross sections of portions Q.

Third, assuming *arguendo* that there is no way to schematically show the lowest fatigue strength portion, the Statute under 35 USC 112 requires:

> "The specification shall contain a written description of the invention, and of the *manner* and *process of making and using* it, *in such full, clear, concise, and exact terms . . .*" (Emphasis added).

In the case at hand, Appellant's claim 19 recites:

> "wherein *a lowest fatigue strength portion* which is the lowest in fatigue strength exists *in at least one of the big and small ends,* and *a variable fatigue strength portion* which varies in fatigue strength exists *in each of the first and second joining sections and in the connecting beam section*;
>
> wherein a product of the cross sectional area and the fatigue strength at a cross section of each of the joining and connecting beam section is equal to or greater than *a product of the cross*

> *sectional area and the fatigue strength in the smallest cross sectional area portion in the beam section*." (Emphasis added)

Therefore, the Statute requires Appellant to provide a full, clear, concise, and exact terms in the written description regarding the *manner* and the *process of making and using* of the lowest fatigue strength portion and the variable strength portion. Appellant's disclosure fails to satisfy the statutory description requirement as evidenced by, *e.g.*, paragraphs [0052]-[0066] of the specification and the drawings. In these paragraphs, Appellant describes that the strength distribution of the joining sections can be formed by, *e.g.*, controlling hardening by heat treatment (hardening). However, Appellant admitted that the hardening by heat treatment does not necessarily create the lowest fatigue strength portion in at least one of the big and small ends, and the variable fatigue strength portion in each of the first and second joining sections and in the connecting beam section as seen in Appellant's arguments regarding the rejection under 35 USC 102(b) as being anticipated by JP'317 based on inherency below.

Fourth, in the last paragraph on page 16 of the brief, Appellant submitted that the ordinary artisan would have understood how to make the claimed invention based on the original specification.

On the one hand, Appellant provides no substantial evidence to support the above statement. It is well settled that an expert's opinion on the ultimate legal issue must be supported by some thing more than a conclusory statement. *In re Buchner*, 18 USPQ2d 1331, 1332 (Fed. Cir. 1991). On the other hand, the Court has long laid Appellant's arguments to rest by pointing out that "it is not a question of whether one skilled in the art *might* be able to construct the patentee's device from the teaching of the disclosure. . . Rather, it is a question whether the application necessarily discloses that particular device." *Lockwood v. American Airlines, Inc.*,

41 USPQ2d 1961, 1966 (Fed. Cir. 1997) and cases cited therein. "It is not sufficient for purposes of the written description requirement of 112 that the disclosure, when combined with the knowledge in the art, would lead one to *speculate* as to modifications that the inventor might have envisioned, but failed to disclose. Each application in the chain *must* describe the claimed features." (Emphasis added). *Lockwood* at 1966.

Applying this rule to the instant case, Appellant's claims specifically call for the lowest and variable fatigue strength portions, *a fortiori*, Appellant must describe how these claimed portions are formed *in such full, clear, concise, and exact terms.* Appellant's specification as filed has failed to meet the requirements under 35 USC 112 as a matter of law because, *inter alia*, it did not even identify schematically the locations of the claimed lowest and variable fatigue strength portions in the drawings and how these locations are determined.

E. Interview of January 18, 2006

Appellant's tandem arguments on page 17 of the brief about the interview are immaterial since the substance of the interview is not a matter appealable to the Board. MPEP 1201.

II. 35 USC 112, Second Paragraph

Appellant asserted that the claimed portions are self-defining, thus, it is clear which portions of the connecting rod are which.

The Examiner is mindful that although the terms of a claim may appear to be definite as alleged by Appellant, inconsistency with the specification disclosure or prior art teaching may make an otherwise definite claim take on an unreasonable degree of uncertainty. MPEP 2173.03 and cases cited therein. In the case *sub judice*, the claims are inconsistent with the specification disclosure because although the specification describes the process, such as, hardening and

tempering, and the composition of the materials of which the connecting rod is made, however, the specification does not describe and the drawings do not show, *inter alia*, the claimed lowest and variable fatigue portions *as claimed in "wherein" clause of claim 19.* Consequently, one skilled in the art would not be able to determine the metes and bounds of the claims when read in light of the specification.

III. 35 USC 102

1. JP'317

At the outset, Appellant contended that JP'317 does not inherently teach the "wherein" clause in claim 1. The Examiner respectfully submits that Appellant's instant arguments are inconsistent with Appellant's arguments regarding the rejection under 35 USC 112, first paragraph, above. On the one hand, Appellant admitted that "*Appellant **do not deny** the use of heat-treatment in obtaining embodiments of their connecting rod, **although the use of heat treatment is not recited in claim 1.***" See last paragraph on page 23 of the brief. On the other hand, Appellant argued that even though JP'317 used the heat treatment in obtaining JP'317's connecting rod, but JP'317's connecting rod does not inherently have the same or similar characteristics. See *In re King*, 801 F.2d 1324, 231 USPQ 136 (Fed. Cir. 1986) and *In re Best*, 562 F.2d 1252, 1255 n.4, 195 USPQ 430, 433 n.4 (CCPA 1977) and MPEP 2112.

Returning to JP'317, this reference teaches the connecting rod made of steel comprising C, Si, Mn, Cr as seen in claims 1-5 of JP'317 on pages 2 and 3 of the translation. Appellant also uses the steel comprising C, Si, Mn, and Cr as seen in Appellant's claims 21 and 22. More importantly, both JP'317 and Appellant used the controlled hardening by heat treatment to change the proportion (%) of martensite of the steel. See, *e.g.*, Appellant's claims 2 and 3 and

paragraph [0052] of Appellant's specification, and compare with the description on pages 6-10 of the translation of JP'317 and its Derwent English Abstract. Since Appellant and JP'317 used the same method to harden the steel, therefore, the end results, *i.e.*, the change of the martensite must happen in the same manner. This fact is supported by standard textbooks of mechanical design, such as, page 17-15 through page 17-20 of *Mechanical Design and Systems Handbook* attached to the brief.

To the extent that claim 1 recites "each of the first and second joining sections gradually and continuously decreases in cross sectional area toward the connecting beam section and has a strength distribution in which a *strength increases with a decrease in the cross sectional area*," JP'317 shows the first and second joining sections gradually and continuously decreases in cross sectional area toward the connecting beam section in Figs. 11 and 12. Moreover, in paragraph [0040] on page 12 of the translation, JP'317 expressly describes that the I section (*i.e.*, the connecting beam section) is finely worked. Paragraph [0042] of the translation further describes that the hardness is reduced in the stage before the perform work. In other words, JP'317 also used the controlled hardening as described in paragraph [0052] of Appellant's specification. The results of the measuring of the hardness of each sections A-A', B-B', and C-C' are shown in Fig. 12 (see paragraph [0061] to [0063]). This Fig. 12 shows that at the smallest cross sectional area B-B of the big end, the hardness is in the range of 390-401, meanwhile, at the largest cross sectional area A-A' of the beam, the hardness is in the range of 394-397, and at the intermediate cross sectional area C-C' of the small end, the hardness is in the range of 396-399. These ranges of hardness show that *the strength increases with a decrease in the cross sectional area* because at the smallest cross sectional area A'A' of the beam, the hardness is greater than the hardness of

the cross sections of the small and big ends as shown by mathematical symbols, such as, 401 > 399 > 397. In a few words, Fig. 12 of JP'317 is the evidence to show that since both Appellant and JP'317 used the same controlling hardening method, therefore, it *must* result in the same way, i.e., the strength increases with a decrease in the cross sectional area. See MPEP 2112 and cases cited therein.

In summary, the use of the controlled hardening method to form JP'317's connecting rod and the results of the measurement of hardness of different sections of the connecting rod of JP'317 in comparison with the hardness of the cross sections of a practical (prior art) connecting rod in Fig. 12 of JP'317 (see page 12 of the translation) are the substantial evidence to show that JP'317 teaches the strength increases with a decrease in cross sectional area as claimed.

Our reviewing Court recently reiterated that a reference may anticipate even when the relevant properties of the thing disclosed were not appreciated at the time. The court refused to apply precedent that distinguished a new patent as directed to a purpose different from the prior patent, pointing out that such a distinction applies only to process claims, not composition claims. *Abbott Laboratories v. Baxter Pharmaceutical Products, Inc.*, Fed. Cir., No. 06-1021, 11/10/2006. Therefore, even if the relevant properties, such as, the strength increases with a decrease in the cross sectional area were not appreciated at the time of JP'317's invention was made, to the extent that Appellant's discovery of this inherent result from the controlled hardening method, Appellant should be denied the patent rights for the product claims in this case.

Finally, in the third paragraph on page 31 of the brief, Appellant contended that there is no reference to temperature in the Derwent English Abstract. The Examiner respectfully submits

that the Abstract is merely a concise statement of the technical disclosure of the invention. MPEP 608.01(b). Appellant is respectfully referred to the full text translation wherein the temperature range of, *e.g.*, 550 to 950^{o} C on pages 10-14 and shown in Figs. 2, 4, 5, 7, and 9 (see pages 20 and 21 of the translation).

For the foregoing reasons, the Examiner respectfully submits that the rejection based on JP'317 be affirmed.

2 & 3. Mrdjenovich et al. and Haman

In the same vein of arguments, Appellant contended that Mrdjenovich or Haman does not teach the strength distribution increases with a decrease in the cross sectional area.

The Examiner respectfully submits that Appellant admitted that "*Appellant **do not deny** the use of heat-treatment in obtaining embodiments of their connecting rod, **although the use of heat treatment is <u>not</u> recited in claim 1.***" See last paragraph on page 23 of the brief. In other words, Appellant's claim 1 is *de facto* a product-by-process claim similarly to claims 4 and 25. This claim has a "wherein" clause that merely recites an inherent result of the process step "heat treatment."

The Examiner is mindful that "when the prior art discloses a product which reasonably appears to be either *identical with or only slightly different* than a product claimed in a product-by-process claim, a rejection based alternatively on either section 102 of section 103 of the statute is eminently fair and acceptable. As a practical matter, the Patent Office is not equipped to manufacture products by myriad of processes put before it and then obtain prior art products and make physical comparison therewith." MPEP 2113 citing *In re Brown*, 459 F2d 531, 535, 173 USPQ 685, 688 (CCPA 1972).

Here, the connecting rod of Mrdjenovich or Haman is *either identical with or only slightly different* than Appellant's claimed connecting rod. Therefore, the rejection under 35 USC 102 is eminently fair and acceptable as approved by the Court. Once the examiner provides a rationale tending to show that the claimed product appears to be the same or similar to that of the prior art, although produced by a different process, the burden shifts to applicant to come forward with evidence establishing an unobvious difference between the claimed product and the prior art product. *In re Marosi*, 710 F.2d 798,802, 218 USPQ 289, 292 (Fed. Cir. 1983) cited in MPE 2113.

Appellant has not come forward with evidence establishing the unobvious difference. In the absence of the rebuttal evidence, the rejection should be approved pursuant to the Court mandate.

(11) Related Proceeding(s) Appendix

No decision rendered by a court or the Board is identified by the Examiner in the Related Appeals and Interferences section of this Examiner's answer.

CONCLUSION

For the above reasons, it is believed that the rejections should be sustained.

Respectfully submitted,

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Primary Examiner

Conferees on September 19, 2006:

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APPENDIX

PTO 06-2175

CY=JA DATE=19981117 KIND=A
PN=10-306317

METHOD FOR MANUFACTURING CONNECTING ROD
[KONIKUTEINGU RODDO NO SEIZO HOHO]

Hiroaki Yoshida, et al.

UNITED STATES PATENT AND TRADEMARK OFFICE
Washington, D.C. February 2006

Translated by: FLS, Inc.

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INVENTOR	(72):	YOSHIDA, HIROAKI, ET AL.
APPLICANT	(71):	DAIDO STEEL CO., LTD., ETC.
TITLE	(54):	METHOD FOR MANUFACTURING CONNECTING ROD
FOREIGN TITLE	[54A]:	KONEKUTEINGU RODDO SEIZO HOHO

(54) [Title of the Invention] /1*

METHOD FOR MANUFACTURING CONNECTING ROD

[Claim(s)] /2

[Claim 1] A method for manufacturing a connecting rod having high strength and high accuracy characterized by making a stock from a steel containing 0.04 to 0.15% C and 0.08 to 0.50% Si, by wt. %, and further, containing, as a quenchability-improving element, one or more elements selected from among 3.0% or less Mn, 3.0% or less Cr, 4.0% or less Ni, 1.0% or less Cu, 3.0% or less Mo, 0.5% or less W, 0.5% or less Ta, 0.3% or less V, 0.08% or less Nb, 0.01% or less B in a range where the manganese equivalent (Mneq) exhibiting a quenchability represented by the expression below:

$3.4 \leq Mneq \leq 6.0$

((Mneq=Mn(%)+Cr(%)+Ni(%)/2+Cu(%)+Mo(%)+W(%)+Ta(%)+V(%)+10(Nb(%)-0.02)+XB)

(provided XB=1.0 when between 0.0005% and 0.01% of B is contained))

and comprising a balance of Fe and impurities; using the stock as is in an unrolled state or after subjecting it to a softening treatment, such as annealing, to perform plastic work, such as cold forging or rolling, in advance, or preform work by machining; then heating at or above the A_{C3} point once as a blank for forging; performing forging work into a connecting rod shape in a temperature range of 550 to 950°C; and subsequently transforming it into martensite by performing quenching by cooling with water, cooling

* Number in the margin indicates pagination in the foreign text.

with oil, or the like.

[Claim 2] The method for manufacturing a connecting rod having high strength and high accuracy of Claim 1 characterized by including one or more kinds of elements selected from 0.1% or less Al and 0.1% or less Ti in the steel as a nitride-forming element.

[Claim 3] The method for manufacturing a connecting rod having high strength and high accuracy of Claim 1 or 2 characterized by including one or more elements selected from among 0.3% or less S, 0.3% or less Pb, 0.15% or less Bi, 0.1% or less Te, or 0.05% or less Ca in the steel as a machinability-improving element.

[Claim 4] The method for manufacturing a connecting rod having high strength and high accuracy of Claim 1 or 2 characterized by performing an aging treatment for one or more minutes in a temperature range of 200 to 600°C after performing quenching by cooling with water, cooling with oil, etc.

[Claim 5] The method for manufacturing a connecting rod having high strength and high accuracy of any of Claims 1 to 4 characterized by performing a shot peening treatment after performing quenching by cooling with water, cooling with oil, or the like.

[Detailed Specifications]

[0001] [Technical Field of the Invention]

The present invention relates to a method for manufacturing a connecting rod having high strength and high accuracy suitable for manufacturing a connecting rod, which is utilized for connecting a piston and a crank

shaft in a reciprocating engine, to have high strength and high accuracy.

[0002] [Prior Art]

While manufacturing a connecting rod, generally hot forging has been adopted in the past by a burring method.

[0003] However, there are drawbacks because it is difficult to ensure sufficient accuracy with a hot forging in such a burring method, and moreover, the material yield is fairly poor.

[0004] In order to engineer a more highly accurate connecting rod, in recent years, although a closed forging method has been put to practical use without generating burrs, this closed forging method has a drawback because the forging load is considerably high.

[0005] Moreover, in order to increase accuracy even more, attempts at using a highly precise blank to reduce the forging temperature even more by performing a cold performing prior to forging, and so forth has been attempted.

[0006] When an increase in strength is considered to increase the strength above 1,100 MPa and to decrease the weight of such a highly accurate connecting rod, problems were presented because this could not be corresponded sufficiently by a conventional type of ferrite/perlite steel, and moreover, it was difficult to ensure high accuracy with a quenched and tempered stiff steel owing to warpage, distortion, cracking, and the like during the heat treatment.

[0007] Consequently, in order to enable manufacture of a connecting rod having high strength and high accuracy, there were issues because

a material was required so that the cold preformability (cold forgability) was satisfactory, the warm forgability during a closed forging, and further, quenching from a relatively low temperature could be performed after the warm forging.

[0008] [Object of the Invention]

The present invention was accomplished in view of such conventional problems, and it is an object to be able to manufacture a connecting rod having high strength and high accuracy, with steel as the stock, having satisfactory cold preformability (cold plastic workability, such as cold forgability), outstanding warm forgability during a closed forging, and which can be quenched from a relatively low temperature after warm forging.

[0009] [Means for Solving the Problems]

The method for manufacturing a connecting rod pertaining to the present invention is characterized by making a stock from a steel containing 0.04 to 0.15% C and 0.08 to 0.50% Si, by wt. %, and further, containing, as a quenchability-improving element, one or more elements selected from among 3.0% or less Mn, 3.0% or less Cr, 4.0% or less Ni, 1.0% or less Cu, 3.0% or less Mo, 0.5% or less W, 0.5% or less Ta, 0.3% or less V, 0.08% or less Nb, 0.01% or less B in a range where the manganese equivalent (Mneq) exhibiting a quenchability represented by the expression below:

$3.4 \leq Mneq \leq 6.0$ /3

$((Mneq=Mn(\%)+Cr(\%)+Ni(\%)/2+Cu(\%)+Mo(\%)+W(\%)+Ta(\%)+V(\%)+10(Nb(\%)-0.02)+XB)$

(provided XB=1.0 when between 0.0005% and 0.01% of B is contained))

and comprising a balance of Fe and impurities; using the stock as is in an unrolled state or after subjecting it to a softening treatment, such as annealing, to perform plastic work, such as cold forging or rolling, in advance, or preform work by machining; then heating at or above the A_{C3} point once as a blank for forging; performing forging work into a connecting rod shape in a temperature range of 550 to 950°C; and subsequently transforming it into martensite by performing quenching by cooling with water, cooling with oil, or the like.

[0010] In an embodiment of the method for manufacturing a connecting rod pertaining to the present invention, as described in claim 2, one or more kinds of elements selected from 0.1% or less Al and 0.1% or less Ti in the steel as a nitride-forming element are included.

[0011] Similarly, in an embodiment of the method for manufacturing a connecting rod pertaining to the present invention, as described in claim 3, one or more elements selected from among 0.3% or less S, 0.3% or less Pb, 0.15% or less Bi, 0.1% or less Te, or 0.05% or less Ca are included in the steel as a machinability-improving element.

[0012] Similarly, in an embodiment of the method for manufacturing a connecting rod pertaining to the present invention, as described in claim 4, an aging treatment is performed for one or more minutes in a temperature range of 200 to 600°C after performing quenching by cooling with water, cooling with oil, etc.

[0013] Similarly, in an embodiment of the method for manufacturing a connecting rod pertaining to the present invention, as described in

claim 5, a shot peening treatment is performed after performing quenching by cooling with water, cooling with oil, or the like.

[0014] [Effects of the Invention]

Reasons for limiting the chemical componential composition (wt.%) of the steel applied in the method for manufacturing a connecting rod pertaining to the present invention are described next.

[0015] C: C is an element which determines the martensitic hardness according to its content, and moreover, it has an effect to increasing the resistance to deformation in the case of a metastable austenite. As a consequence, by keeping the C content in a range of 0.04 to 0.15%, the resistance to deformation is low in the case of a metastable austenite, and further, a strength of about 1,100 to 1,600 MPa can be ensured.

[0016] Si: Si is an element for enhancing the quenchability of steel, but since it simultaneously increases the resistance to deformation, above all, a cold resistance to deformation, the Si content was set to a range of 0.08 to 0.50%.

[0017] Mn: Mn is an element that enhances the quenchability of steel, but similar to Si, it also increases the resistance to deformation. Consequently, the upper limit of the Mn content was set to 3.0% or less.

[0018] Cr: Cr is an element that enhances the quenchability of steel, and moreover, it is an element that enhances the resistance to annealing softening by depositing a carbide thereof during tempering. However, Cr readily produces a primary carbide which reduces the deformability during forging, so the content was set to 3.0% or less.

[0019] Ni, Cu: Ni and Cu are elements that enhance the quenchability of steel without increasing the resistance to deformation, but even if large amounts of these elements are used, there no more effects thereby; hence, the amount of Ni was set to 4.0% or less and that of Cu to 1.0% or less.

[0020] Mo, W and Ta: Mo, W and Ta are elements for enhancing the quenchability of steel and also for enhancing the resistance to tempering softening. However, as with Cr, they act in reducing the deformability during forging acts; hence, the Mo was set to 3.0% or less, W was set to 0.5% or less and Ta was set to 0.5% or less.

[0021] V: Since V is an effective element for enhancing the quenchability of steel upon setting the content to 3% or less, it was set to 0.3% or less.

[0022] Nb: Nb is an effective element for enhancing the quenchability of steel, but since its degree of solid solution is considerably low, the upper limit thereof was set to 0.08%.

[0023] B: B has an effect for remarkably enhancing the quenchability of steel in extremely small quantities, and more desirably is set to 0.0005% or higher. However, if the content is too high, the quenchability decreases; hence, it was set to 0.01% or less.

[0024] Al: Al has an effect for ensuring satisfactory toughness by preventing the crystal grains from coarsening by bonding to N to form a stable nitride. However, if the content is too high, the forgability is reduced; hence, it was set to 0.1%.

[0025] Ti: As with Al, Ti has an effect for ensuring satisfactory toughness by preventing the crystal grains from coarsening by forming a stable nitride. Moreover when B is added, it has an effect in preventing it from becoming BN. However, since the forgability is reduced if the content is increased, it was set to 0.1%.

[0026] S, Pb, Bi, Te and Ca: S, Pb, Bi, Te and Ca have an effect for enhancing the machinability of steel, but they also are elements that inhibit forgability; hence, even if they are included, the S was set to 0.3% or less, the Pb was set to 0.3% or less, the Bi was set to 0.15% or less, the Te was set to 0.1% or less and the Ca was set to 0.05% or less.

[0027] Fe: Fe is a basic constituent of steel, with it, /4
therefore, rounding out the balance.

[0028] Mneq: The manganese equivalent (Mneq) which indicates the quenchability of steel is:

$$Mneq=Mn(\%)+Cr(\%)+Ni(\%)/2+Cu(\%)+Mo(\%)+W(\%)+Ta(\%)+V(\%)+10(Nb(\%)-0.02)+XB$$

(Provided it is calculated when 0.005% to 0.01 of B is included, but when this **Mneq** is 3.4 or higher, a stabilized forging and quenching are possible; hence, the **Mneq** was set to 3.4 or higher. On the other hand, when the **Mneq** is 6.0 or less, outstanding forgability, above all, outstanding deformability is exhibited. By setting **Mneq** to 6.0 or less, a satisfactory cold preform workability can be obtained; hence, the **Mneq** was set to 6.0 or less.

[0029] Steel having such a chemical componential composition and to which the present invention was applied has satisfactory cold preform workability (cold plastic workability, such as cold forgability) and also outstanding warm forgability during a closed forging, and moreover a relatively low-temperature quenching can be performed after a warm forging.

[0030] With the method for manufacturing a connecting rod of the present invention, by making a stock from a steel having the above-mentioned chemical componential composition, and using the stock as is in an unrolled state or after subjecting it to a softening treatment, such as annealing, to perform plastic work, such as cold forging or rolling, in advance, or preform work by machining; then heating at or above the A_{c3} point once as a blank for forging; performing forging work into a connecting rod shape in a temperature range of 550 to 950°C; and subsequently transforming it into martensite by performing quenching by cooling with water, cooling with oil, or the like, but this will be described further. Moreover, in the following description, this will be described on the basis of the results of examining the various characteristics shown in Figures 3 to 10 by using steel having the chemical componential compositions and the manganese equivalents (Mneq) shown in Tables 1, 2 and 3.

[0031] [Table 1]

/5

Grade	Chemical Constituents (wt.%)										Manganese Equivalent
	C	Si	Mn	P	S	Cr	Ni	Mo	B	Ti	(Mneq)
A	0.04	0.22	2.0	0.014	0.015	1.0	0.02	0.02	0.002	0.025	4.0
B	0.06	0.20	1.5	0.013	0.012	0.5	0.02	0.03	–	–	2.0
C	0.06	0.18	1.5	0.011	0.013	0.5	0.03	0.2	–	–	2.2
D	0.06	0.23	1.5	0.011	0.011	0.6	0.02	0.02	0.001	0.021	3.1
E	0.06	0.21	1.5	0.013	0.018	1.0	0.02	0.02	0.001	0.025	3.5
F	0.06	0.20	1.5	0.014	0.013	1.0	0.03	0.5	0.002	0.023	4.0
G	0.06	0.20	1.5	0.013	0.016	1.2	1.61	0.01	0.003	0.025	4.5

[0032] [Table 2]

/6

Grade	Chemical Constituents (wt.%)										Manganese Equivalent
	C	Si	Mn	P	S	Cr	Ni	Mo	B	Ti	(Mneq)
H	0.05	0.21	2.0	0.013	0.013	1.2	1.62	0.01	0.002	0.024	5.0
I	0.06	0.22	2.5	0.012	0.013	1.2	1.60	0.01	0.002	0.025	5.5
J	0.06	0.25	2.5	0.013	0.014	1.5	0.02	1.0	0.002	0.023	6.0
K	0.06	0.25	3.0	0.013	0.014	1.5	0.02	1.0	0.002	0.023	6.5
L	0.11	0.19	2.0	0.014	0.013	1.0	0.03	0.01	0.002	0.022	4.0
M	0.15	0.21	2.0	0.013	0.012	1.0	0.04	0.03	0.002	0.024	4.0
N	0.20	0.22	2.0	0.011	0.012	1.0	0.02	0.02	0.003	0.023	4.0

[0033] [Table 3]

/7

Grade	Chemical Constituents (wt.%)										Manganese Equivalent
	C	Si	Mn	P	S	Cr	B	Ti	Bi	Te	Ca	(Mneq)
O	0.06	0.22	2.0	0.014	0.050	1.0	0.001	0.025	–	0.006	–	4.0
P	0.06	0.20	2.0	0.013	0.052	1.0	0.002	0.022	0.10	0.006	–	4.0
Q	0.06	0.18	2.0	0.011	0.055	1.0	0.002	0.023	0.10	–	0.004	4.0

[0034] Normally, when quenching is performed from a nonrecrystallized austenite comprising a metastable (500°C or higher) austenite and subjected

to a work quenching, since the formation of ferrite, perlite and bainite, which is a diffusional transformation, is accelerated markedly, the quenchability decreases significantly.

[0035] As a consequence, in order to perform forging and quenching from a low temperature as in the present invention, a sufficient quenchability must be ensured.

[0036] Conversely, if sufficient quenchability can be ensured, considerably high strength can be obtained by quenching from a work-hardened austenite.

[0037] When a metastable austenite is subjected to a forging work, the resistance to deformation primarily increases in proportion to the C content. This is because the C forms a solid solution in the austenite.

[0038] The resistance to deformation at this time is a value that is considerably larger when the temperature is the same than when working is applied immediately after heating to the forging temperature right away (in the usual method).

[0039] Each steel having the above-mentioned chemical componential compositions to which the present invention is applied is a component system that hardly softens by tempering or the like, while the resistance to deformation could be reduced, by contrast, by keeping the C content low. This is because the steel can be forged in the austenite region where there is a small amount of C in solid solution.

[0040] In order to enhance the accuracy of a connecting rod, the preform work performed in advance is applied to the issue of how the I

section (rod section) is finely worked.

[0041] Although plastic working, such as forging work, rolling work and spinning work, machining work, and the like have been considered for the preforming work in this case, in deliberation of an actual manufacturing, plastic working is more preferable than machining work. In order to work the rod to higher accuracy, a cold working is desired.

[0042] Therefore, the hardness is reduced in the stage before the preform work, it is demanded that the deformability also be sufficiently high.

[0043] Therefore, it is desired that the composition after rolling be mainly ferrite, or mainly bainite, but because of the above-mentioned quenchability problem, the structure should be mainly bainite.

[0044] By setting the upper limit of the manganese equivalent (Mneq) to 6.0, a structure comprising mainly bainite and very low in C can be obtained, and thus, a satisfactory cold forgability can be obtained. Incidentally, it is well known that a bainite very low in C has a structure extremely abundant in ductility.

[0045] The quenchability after forging is mentioned next.

[0046] As in the present invention, once quenching is performed after a plastic working, such as forging (in the case of a Process 1 shown in Figure 1(A)), in a temperature range of 550 to 950°C near the metastable austenite region after heating at or above the A_{c3} point (e.g., 850°C or higher), as shown in Figure 2, there is a large shift substantially to the left for a nose of ferrite deposited and transformed in a diffusional

manner.

[0047] Therefore, in order to realize a stabilized quenchability, large amounts of Mn, Cr, and the like, which are quenchability-improving elements, should be contained to delay ferrite transformation, or perlite or bainite transformation. Therefore, the total amount of these elements is represented by the manganese equivalent (Mneq), which was set to 3.4 or higher in the present invention.

[0048] Figure 3 shows a relationship between the manganese equivalent (Mneq) and hardness (Hv) after forging and quenching. Moreover, Figure 4 shows a relationship between the forging temperature and tensile strength. As seen from Figure 3, when the manganese equivalent (Mneq) is 3.4 or /8
higher, a stabilized forging quenching is possible. Also, as seen from Figure 4, by performing a plastic working, such as forging, in a temperature range of 550 to 950°C, a higher strength is obtained than in a quenching-only state (in the case of Process 2). This is because the same process is used as for ausforming, which is a working heat treatment.

[0049] Figure 5 shows a relationship between the aging temperature and strength when an aging treatment is performed in a temperature range of 100 to 700°C after forging and quenching. But by performing an aging treatment of at least 1 minute in a temperature range of 100 to 700°C, and more preferably, 200 to 600°C after forging and quenching, the strength, above all, the yield strength is higher than in a quenching-aging treatment without performing forging, thus superiority is manifested.

[0050] The forgability is mentioned next.

[0051] The resistance to deformation during forging in Processes 1 and 2 shown respectively in Figures 1(A) and (B) is shown in Figure 6.

[0052] As seen from Figure 6, the resistance to deformation in Process 1 is lower than the resistance to deformation in Process 2. With a material having very low C and an **Mneq** of 3.4 or higher, since austenite having a smaller amount of C in solid solution is softer than ferrite and bainite fine cementite, which is a post-tempered structure, the resistance to deformation during the forging in Process 1 is lower. In addition, it is primarily a relationship in which the hardness hardly decreases by a softening heat treatment, such as annealing.

[0053] Figure 7 shows the results of investigating a relationship between the C content and the resistance to deformation. The effect of the C content is the largest on resistance to deformation having a low-temperature **γ**. Figure 7 reflects those results well. It is desirable that the material suitable for a warm forging (γ region) be a low C-content steel, such as the steel to which the present invention is applied.

[0054] Figure 8 shows the results of investigating the relationship between the manganese equivalent (Mneq) after a low-temperature tempering (680°C×2 h/AC), cold resistance to deformation, and critical compressibility. At this time, the rolled structure exhibits ferrite, or mainly bainite conditions, that is, outstanding forgability, above all, excellent deformability if the manganese equivalent (Mneq) is 6.0 or less.

[0055] As a consequence, since the upper limit of the manganese equivalent (Mneq) is set to 6.0, an outstanding cold preformability can be obtained. Conversely, when the manganese equivalent (Mneq) is greater than 6.0, it is improved by performing a considerably long softening treatment, but this is not preferred from a cost standpoint.

[0056] Figure 9 shows the results of investigating a relationship between the forging temperature and the tensile strength of steel containing a free-cutting constituent. Figure 10 shows the results of investigating the critical compressibility of steel containing a free-cutting constituent. But even when a free-cutting constituent is included, the strength and excellent cold forgability can be ensured after a satisfactory forging and quenching.

[0057] [Practical Examples]

In this practical example, the steel having the chemical componential compositions shown in Table 4 were used as the stock.

[0058] [Table 4]

Grade	Chemical Constituents (wt.%)										Manganese Equivalent
	C	Si	Mn	P	S	Cr	Ni	Mo	B	Ti	(Mneq)
B	0.06	0.20	1.5	0.013	0.012	0.5	0.02	0.03	-	-	2.0
F	0.06	0.20	1.5	0.014	0.013	1.0	0.03	0.5	0.002	0.023	4.0

[0059] By cutting it from stock in a rolled state as is, a bar stock **11** was prepared, as shown in Figure 11(A), after which a cold preform-worked compact **12** having a part **12a** corresponding to the large end portion, a part **12b** corresponding to the rod portion, and a part **12c** corresponding

to the small end part was obtained, as shown in Figure 11(B).

[0060] Next, by performing a warm (closed) forging at a temperature of 800°C after heating to 820°C at or above the A_{c3} point once, with the cold preform-worked compact **12** as the blank, a plastic working was performed into the shape of a connecting rod compact **13** having a large end /9
portion **13a**, rod portion (I section) **13b** and small end part **13c**, as shown in Figure 11(C). After that, by performing quenching by oil cooling (the time until quenching right after forging was about 20 seconds), a connecting rod **14** having a large end portion **14a**, rod portion (I section) **14b** and small end portion **14c** was obtained. Moreover, the shape after the forging working was remarkably satisfactory with both steel grades, as shown in Figure 11(D).

[0061] Upon measuring the hardness of each connecting rod at the positions shown in Figure 12 (A-A', B-B' and C-C'), the results are as shown in Figure 12.

[0062] As seen from Figure 12, the hardness after quenching varies greatly between a steel grade **F** and steel grade **B**, the manganese equivalent (Mneq) of the steel grade **B** was unsatisfactory; hence, the structure after quenching was almost entirely bainite and the hardness was low.

[0063] Vis-à-vis, the steel grade **F** exhibited a stabilized hardness distribution, the structure was entirely martensite, and a connecting rod having high strength and high accuracy could be manufactured.

[0064] [Advantages of the Invention]

Since, with the method for manufacturing a connecting rod according to the present invention, a stock is made from a steel containing 0.04 to 0.15% C and 0.08 to 0.50% Si, by wt. %, and further, containing, as a quenchability-improving element, one or more elements selected from among 3.0% or less Mn, 3.0% or less Cr, 4.0% or less Ni, 1.0% or less Cu, 3.0% or less Mo, 0.5% or less W, 0.5% or less Ta, 0.3% or less V, 0.08% or less Nb, 0.01% or less B in a range where the manganese equivalent (Mneq) exhibiting a quenchability represented by the expression below:

$3.4 \leq Mneq \leq 6.0$

((Mneq=Mn(%)+Cr(%)+Ni(%)/2+Cu(%)+Mo(%)+W(%)+Ta(%)+V(%)+10(Nb(%)-0.02)+XB)

(provided XB=1.0 when between 0.0005% and 0.01% of B is contained))

and comprising a balance of Fe and impurities; the stock is used as is in an unrolled state or after subjecting it to a softening treatment, such as annealing, to perform plastic work, such as cold forging or rolling, in advance, or preform work by machining; then heated at or above the A_{c3} point once as a blank for forging; forging work into a connecting rod shape is performed in a temperature range of 550 to 950°C; and subsequently it is transformed into martensite by performing quenching by cooling with water, cooling with oil, or the like, exceptionally substantial effects are manifested in that a connecting rod having high strength and accuracy can be manufactured wherein cold preformability (cold plastic workability) is satisfactory, the cold forging during a closed forging is outstanding,

and a steel that can be quenched from a relatively low temperature after a cold forging can be used as the stock.

[0065] Because, as described in claim 2, one or more kinds of elements selected from 0.1% or less Al and 0.1% or less Ti in the steel as a nitride-forming element are included, exceptionally substantial effects caused in that a connecting rod having high strength and accuracy can be manufactured and even more outstanding in toughness, with finer crystal grains.

[0066] Furthermore, because, as described in claim 3, one or more elements selected from among 0.3% or less S, 0.3% or less Pb, 0.15% or less Bi, 0.1% or less Te, or 0.05% or less Ca are included in the steel as a machinability-improving element, exceptionally substantial effects are manifested in that the cutting workability of the stock during forging can be improved even more.

[0067] Still further, because, as described in claim 4, an aging treatment is performed for one or more minutes in a temperature range of 200 to 600°C after performing quenching by cooling with water, cooling with oil, etc., exceptionally substantial effects are manifested in that a connecting rod having more improved strength, above all, yield strength can be obtained.

[0068] Further yet, because, as described in claim 5, a shot peening treatment is performed after performing quenching by cooling with water, cooling with oil, or the like.

[Brief Description of the Drawings]

[Figure 1] is an explanatory diagram showing a basic process (Process 1) in the method for manufacturing a connecting rod according to the present invention (Figure 1(A)) and a basic process (Process 2) in a method for manufacturing a connecting rod (Figure 1(B)) in general.

[Figure 2] is an explanatory diagram showing an aspect in which there is a large shift substantially to the left for a nose of ferrite deposited and transformed in a diffusional manner when quenching is performed after a forging in a temperature range of 550 to 950°C which is close to the metastable austenite region subsequent to heating once at 850°C or higher.

[Figure 3] is a graph illustrating the results of investigating a relationship between manganese equivalent (Mneq) and hardness after forging and quenching.

[Figure 4] is a graph illustrating the results of investigating a relationship between forging temperature and tensile strength.

[Figure 5] is a graph illustrating the results of investigating a relationship between aging temperature and strength when an aging treatment is conducted in a temperature range of 100 to 700°C after forging and quenching.

[Figure 6] is a graph illustrating the results of investigating a relationship between forging temperature and resistance to deformation.

[Figure 7] is a graph illustrating the results of investigating /10
a relationship between C content and resistance to deformation.

[Figure 8] is a graph illustrating the results of investigating a

relationship between manganese equivalent (Mneq), resistance to deformation, and critical compressibility after a low-temperature annealing.

[Figure 9] is a graph illustrating the results of investigating a relationship between forging temperature and tensile strength of steel comprising a free-cutting constituent.

[Figure 10] is a graph illustrating the results of investigating the critical compressibility of steel comprising a free-cutting constituent.

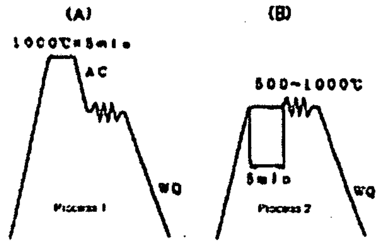
[Figure 11] is an explanatory diagram showing the steps for manufacturing a connecting rod in a practical example of the present invention.

[Figure 12] is an explanatory diagram showing the positions and results of measuring the hardness of a connecting rod obtained in the practical and comparative examples of the present invention.

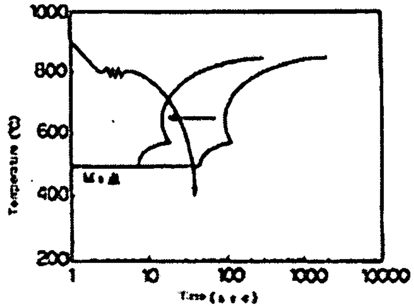
[Explanation of the Codes]

11: stock (bar stock); 12: cold preform-worked compact; 13: connecting rod compact; 14: connecting rod; 14a: large end; 14b: rod portion (I section); 14c: small end portion

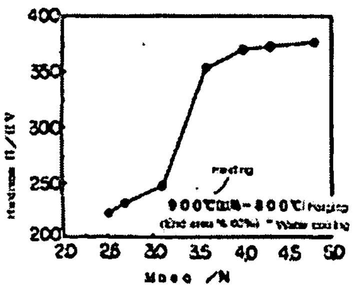
[Figure 1]



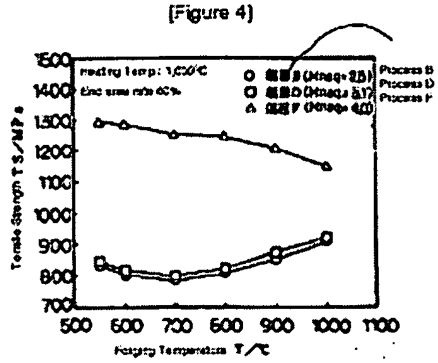
[Figure 2]



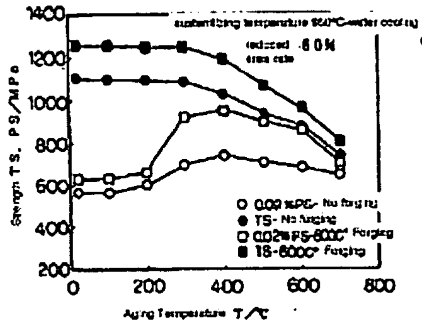
[Figure 3]



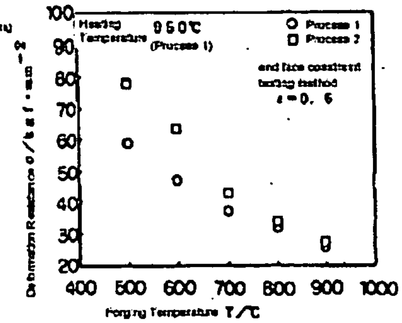
[Figure 4]



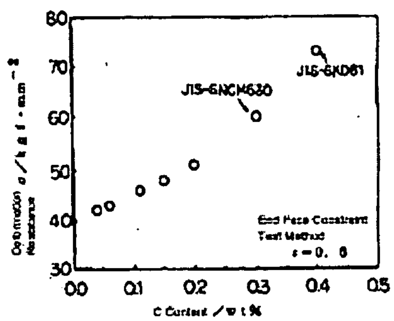
[Figure 5]



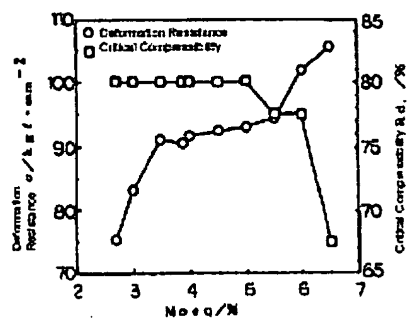
[Figure 6]



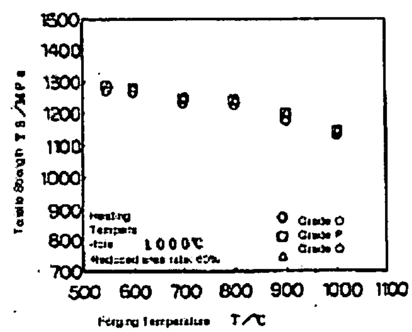
[Figure 7]



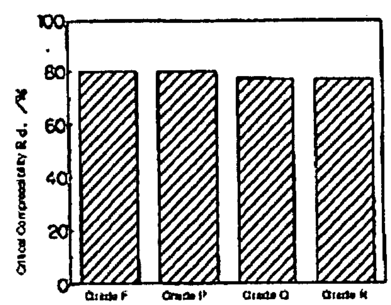
[Figure 8]



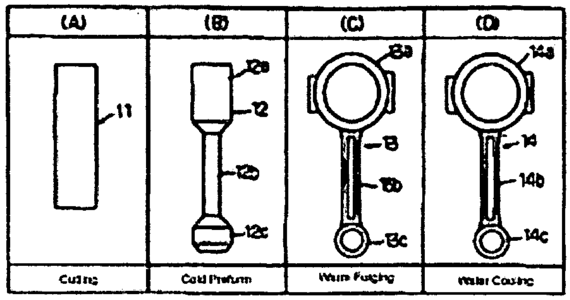
[Figure 9]



[Figure 10]



[Figure 11]



[Figure 12]